(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 288 106 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication of patent specification: **15.12.93** (51) Int. Cl.5: **B01F 3/04**

(21) Application number: **88200661.2**

(22) Date of filing: **07.04.88**

(54) Foamed slurry generator.

(30) Priority: **22.04.87 US 41553**

(43) Date of publication of application:
26.10.88 Bulletin 88/43

(45) Publication of the grant of the patent:
15.12.93 Bulletin 93/50

(84) Designated Contracting States:
DE FR GB IT NL

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Description

BACKGROUND OF THE INVENTION

This invention relates to an apparatus and method for producing foamed cement slurry as used in oil and gas wells. As generally illustrated in US-A-4,457,375; US-A-4,466,833; US-A-3,685,807; and US-A-4,415,366, cement slurries are very useful in drilling operations which include completion, maintenance, and service functions, such as cleaning out sand.

The foam apparatus and method of the prior art has had some deficiencies. As shown in the above patents, the foam generators are relatively complex and do not produce the light density of foam that is sometimes desired. When servicing a well, slurries of different weights are often necessary. A relatively light sand and water slurry under very high pressure is used in fracturing the well. A very heavy cement Slurry may be pumped into the well to displace thick mud after the drilling. The heavy cement is then forced up the sides of the well to form a casing. Heavy slurries are by their nature difficult to pump and, as a result, casings often have to be formed in stages. The stage process is relatively slow and inefficient. When heavy cement slurries are not required by the nature of the well, "foamed" cement slurries, i.e., a gas combined with cement, may be used to displace the liquids in the well and to form the casing. If the slurry is light enough, the casing may be formed by foamed cement in one step.

Care must be taken in the formation of foamed cement slurry to ensure that the slurry itself and the resulting hardened casing are stable. If bubbles that are too big are combined with the slurry, they may rise to the top and thereby defeat the purpose of foaming. If the bubbles of gas are not uniformly distributed, they may combine with each other and cause weakened areas in the concrete casing.

The document US-A-4,647,212 describes a blender for blending or mixing various fluids, especially a liquid with a gas.

A liquid or a gas passes through two perforated plates (11,12) set on two faces of a X - shaped body (10).

However this blender cannot produce a foam.

US-A-4,457,375 describes a foam generator for oilfield applications. However, this document does not aim at forming a foamed cement, but only at circulating a foam in a well.

This invention includes an apparatus and process for uniformly dispersing gas through a slurry to provide a very light, stable liquid. This liquid may be readily pumped into a well to displace the liquid therein and subsequently formed into a casing. The process of forming the casing may usually be done in one step. The present invention has been able to utilize a relatively simple design in producing a very light, stable foam. In particular, a bushing having a number of channels or holes therein separates a stream of gas into a plurality of smaller diameter, higher velocity streams, and achieves a much greater foaming action. Moreover, the use of a particular type of connector which utilizes a twin flow of cement slurry or a twin flow of gas in a mixing chamber also adds to the ability to foam the cement while it is maintained in a stable configuration.

By utilizing this apparatus, a density of 0,108 g/cm^3 (0,9 ppg) has been attained in a stable foam cement slurry. This is a lower density than any practical application that the applicant is aware has ever been achieved. The cement used in the slurry may include additives which are well known in the art. These additives aid in two different degrees in stability, adhesion, foaming action, weight, density, etc. In one actual test, 112 m^3 (705 barrels) Class C, 8,9 l/t (0,1 gallon/SK) foam stabilizer, 1.5% of foaming surfactant pumped at 1,9 m^3/min. (12 barrels per minute), was utilized. Nitrogen was added at a ratio of 1,8 l/l (100 scf/barrel) of slurry throughout the foam stage ; therefore, the nitrogen rate was 34 sm^3/min (1200 scfm). As a result, stable foam cement was circulated to the surface and remained stable.

This invention also includes the process of producing foamed cement slurry by separating a stream of gas into a plurality of high pressure streams, combining it with a plurality of streams of cement slurry at an angle thereto, and subsequently pumping the resulting foamed cement slurry into a well. Alternately, a plurality of nitrogen gas sources may be combined with water and sand in the fracturing process. As used herein, slurry may include cement and/or sand and water.

SUMMARY OF THE INVENTION

This invention relates to a high pressure foam slurry generator which may be cement or sand and water comprising a source of liquid, a source of gas, and means for combining the liquid and the gas in a manner to form small bubbles of gas in the liquid, the means for combining including a housing and a multichannel connector having a mixing area. One channel of the connector is the inlet for the gas, usually nitrogen, which is separated into a plurality of smaller streams of higher velocity. At least one other channel of the inlet acts as an input for the cement slurry. The slurry and the gas, usually nitrogen, are thoroughly mixed in a chamber and transported out of the outlet channel. A third inlet channel may be used for the cement slurry or nitrogen gas for different treatments of the

well. This invention further includes the process of making a foam cement, including pumping a cement slurry capable of being foamed to a housing, pumping a gas to the housing, separating the gas into a plurality of high velocity streams, and combining the streams and the slurry to cause a foaming action. The invention further includes pumping the foamed slurry into a well.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic representation of an apparatus for pumping foamed cement slurry into a well ;

Fig. 2 is a cross section of the connector, foam generator bushing, and adapter of the invention ;

Fig. 3 is a cross-sectional view of the connector of this invention for forming foamed cement slurry ;

Fig. 4 is an end view of the bushing ; and

Fig. 5 is a graphical representation of the pressure versus the flow rates of the gas involved.

DETAILED DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic embodiment of the foam generator of the present invention, as utilized in a drilled well. It includes the foam generator 10, tubing string 12 leading into a well 14 having a casing 16 with a plate 18 at the thereof. The foam generator 10 includes an inlet 20 for a high pressure cement slurry passing through a check valve 22 of any commercially available type to a T-fitting 24. A valve 28 is used to control the various additives to the cement slurry as it passes therethrough. The various additives may be any one of a number of commercially available types for controlling the foaming, amount, density, set-up time, weight, etc. A choke 30 is utilized to control the pressure and velocity of the cement slurry to a desirable level, typically 0,636 to 0,795 m^3/min (four to five barrels per minute) at 70 kg/cm^2 (1000 psi). The choke 30 may be any one of a number of types commercially available and known in the art. A valve 32 controls the volume of the cement slurry to conduit 34, which is operatively attached to a housing 36 by means of connectors 40.

Also leading to the housing 36 is an inlet 42 which is supplied with high pressure gas, such as nitrogen or other gas well known in the art. Such other gases may be carbon dioxide, halogen, freon, etc. The gas is normally under high pressure either from a compressed source or after passing through a compressor (not shown). A check valve 43 ensures that there is no gas flowing back through the conduit 44. A valve 46 controls the input of a foamer or other additive to the gas. A valve 48 controls the input of the treated gas to the housing 36. Typically, the gas is nitrogen and enters at about 210 kg/ cm^2 (3000 psi) at an equivalent of about 2 - 3,2 m^3/ min (about 13-20 barrels/min.), with 2,4-2,5 m^3/min (15-16 equivalent barrels/min.) preferred. The above parameters apply when the housing has about a 63,5 mm (2-1/2 - inch) internal diameter. Other pressures, velocities, and diameters will be obvious to one skilled in the art.

A foam generator bushing 50 (Figs. 1 and 2) separates the source of high pressure nitrogen into a plurality of smaller, high velocity streams. The bushing 50 has a series of channels or holes 52 and a burst disc 58 along its longitudinal axis. The bushing is generally cylindrical in shape, having circular sealing recesses 56 therein. Other shapes will be obvious to one skilled in the art. The bushing 50 is so sized that it will fit into a recess 60 of a connector 62 having a plurality of channels. Inlet channel 64 has female threads therein and an internal diameter slightly larger than that for the recess 60 receiving the insert 50.

As illustrated in Figs. 2 and 3, inlets 68 and 70 may be utilized along with conduits 72 and 74, respectively, which are threadedly engaged therewith to provide inlets for the high pressure cement slurry. An adapter 76, having male threads 78 and a recess 80 properly sized to engage the insert 50, acts to hold the insert in place, as illustrated in Fig. 3. The insert also has male threads 84 at the other end thereof so it may be connected to another conduit. Channels 52 in the insert act to break up the stream of high pressure nitrogen into a plurality of many high velocity streams. The number of streams may vary anywhere from preferably 5 to 25 ; however, it has been found that the use of 16 channels is particularly advantageous. Different diameters may be utilized ; however, 2,4 and 1,19 mm (3/32 inch and 3/64 inch) have also been found to be preferred in the above-described example.

The burst disc 58 is located near the center of the insert, but may be provided in other locations. It has an upwardly facing, convex surface, and may be any one of a number of commercially available burst discs. Burst disc pressure is set well above the operating pressure of the system. Typical of such burst pressures are 700 to 850 kg/cm^2 (10.000 to 12.000 psi). Other safety devices above ground level may also be utilized in different parts of the system.

Important to this system is the maintenance of the foaming action even if the holes 52 should become clogged. If the burst disc 58 ruptures because of clogging in the holes 52, the nitrogen gas will continue to be fed into the connector 62 so that the process of mixing foamed, high pressure cement slurry will continue, albeit not as efficiently.

Similar recesses in the connector 62 are cement slurry recess inlets 86 and 88. All of the inlet

recesses lead to a mixing chamber 90, where the gas and cement slurry or other liquid are mixed. In this particular embodiment, the cross connector has about a 63,5 or 73,02 mm (2 - 1/2 inch or 2 - 7/8 -inch) bore. When using a 63,5 mm (2 - 1/2 - inch) bore connector and 16 1,19 mm (3/64 inch) holes, there is about an 560 kg/cm² (8.000 psi) working pressure. In this case, the typical burst pressure of the disc would be 700 kg/cm² (10.000 psi). If the working pressure were 850 kg/cm² (12.000 psi), the burst pressure of the disc would be about 1050 kg/cm² (15.000 psi).

It is important to note that an alternate embodiment of this invention includes a plurality of bushings 50, i.e., two of them at 90 degrees, i.e., on both sides, from an incoming slurry of sand and water. In this case, the water and sand would typically be at 140 to 850 kg/cm² (2.000 to 12.000 psi) at a rate of 800 - 3.180 l/min (5-20 barrels per minute), and the nitrogen would be 140 kg/cm² (2.000 psi) above the sand and water and have an equivalent input of about 0,795 m³/min (5 barrels per minute) of nitrogen. Both the utilization of two nitrogen gas inputs to a single flow of cement slurry and the use of a single nitrogen stream into two sand and water slurries have been found to produce substantially better results than those previously attained through one of each of the above. In actual tests, the density of foamed cement has been found to be as low as 0,108 g/cm³ (0,9 ppg) with the use of two nitrogen inputs on either side of a cement slurry stream.

In Fig. 3, an outlet 92 includes a recess 94 and female threads 96 in an area of increased diameter for connecting it to a well string.

In Fig. 5 illustrates a graph of the nitrogen rate of flow at 37,8° C (100° F) versus the pressure in the system. It can be seen that there is a straight-line relationship between the pressure and the nitrogen flow rate for the use of 16 channels of 19,05 mm (3/4 -inch) diameter and 16 holes for 2,38 mm (3/32 - inch) diameter. Thus for example, at about 420 kg/cm² (6.000 working psi) using 16 1,19 mm (3/64 - inch) holes, there would be a rate of flow of nitrogen of about 70 m³/min (2.500 cubic feet per minute). Other relationships can be seen from the graph.

Claims

1. A high pressure foam cement slurry generator comprising :
   a source of liquid ;
   a source of gas ;
   means for combining the liquid and the gas in a manner to form small bubbles of gas in the liquid ; the means for combining including a housing (36) and a multi-channel connector (62) having a mixing area (90) operatively attached to inlets and an outlet in the housing ; one channel of the connector being the inlet for the gas (64), at least one channel (68; 70) being the inlet for the slurry, and one channel being the outlet for the foamed slurry ; characterized in that the gas inlet channel has a bushing (50) featuring a series of channels (52) of small diameter, parallel to the longitudinal axis of the said inlet.

2. The high pressure slurry generator of claim 1 characterized in that the bushing has a burst disc (58) mounted therein which bursts if the channels should become clogged and the pressure exceeds a certain limit whereby the mixing of the slurry and gas continues even if the holes become clogged.

3. The high pressure slurry generator of claim 1 or 2 characterized in that there are 16 holes (52) having a diameter of 19,05 mm (3/4 - inch) and the inlet bore has about 63,5 mm (2 - 1/2 inch) diameter.

4. The high pressure slurry generator of claim 1 or 2 characterized in that there are 16 holes (52) having a diameter of 2,32 mm (3/32 - inch) and the inlet bore has a 73,02 mm (2 - 7/8 inch) bore.

5. The high pressure foamed slurry generator of claim 2, characterized in that it has two slurry inlets (68; 70) at right angles to the gas inlet channel (64).

6. The high pressure foamed slurry generator of claim 2, characterized in that it has two gas inlet channels each having a bushing (50) through which the gas passes at right angles to the inlet for the cement.

7. The high pressure foamed slurry generator of claim 3, characterized in that the bushing fits in a recess (60) of the connector (62) and is held in position by an adapter (76) which operatively engages the gas inlet channel (64).

8. The process of making a foamed slurry for use in treating wells comprising :
   pumping a slurry capable of being foamed to a foam generator according to any one of claims 1 to 7;
   pumping a gas to the foam generator;
   characterized in that the said gas is separated into a plurality of high velocity streams.

Patentansprüche

1. Hochdruckzementschlammschaum-Erzeuger umfassend: eine Flüssigkeitsquelle,
eine Gasquelle,
Mittel zum Kombinieren der Flüssigkeit und des Gases in einer derartigen Weise, daß kleine Gasblasen in der Flüssigkeit gebildet werden,
wobei das Mittel zum Kombinieren ein Gehäuse (36) umfaßt, sowie einen Verbinder (62) mit mehreren Kanälen, welcher einen Mischbereich (90) aufweist, der betriebsmäßig mit Einlässen und einem Auslaß in dem Gehäuse verbunden ist, wobei ein Kanal des Verbinders der Gaseinlaß (64) ist, wenigstens ein Kanal (68; 70) der Einlaß für den Schlamm ist, und ein Kanal der Auslaß für den aufgeschäumten Schlamm ist,
dadurch gekennzeichnet,
daß der Gaseinlaßkanal eine Buchse 50 aufweist, welche eine Reihe von Kanälen 52 mit kleinem Durchmesser parallel zur Längsachse des Einlasses aufweist.

2. Hochdruckschlamm-Erzeuger nach Anspruch 1, **dadurch gekennzeichnet,** daß die Buchse eine darin angebrachte Bruchscheibe (58) aufweist, welche bricht, wenn der Kanal verstopft werden sollte und der Druck eine bestimmte Grenze überschreitet, wodurch das Mischen des Schlamms und des Gases selbst dann andauert, wenn die Löcher verstopft werden.

3. Hochdruckschlamm-Erzeuger nach Anspruch 1 oder 2,
dadurch gekennzeichnet, daß 16 Löcher (52) mit einem Durchmesser von 19,05 mm (3/4 - Zoll) vorhanden sind, und die Einlaßöffnung einen Durchmesser von ungefähr 63,5 mm (2-1/2 - Zoll) aufweist.

4. Hochdruckschlamm-Erzeuger nach Anspruch 1 oder 2,
dadurch gekennzeichnet, daß 16 Löcher (52) mit einem Durchmesser von 2,32 mm (3/32 - Zoll) vorhanden sind, und die Einlaßöffnung einen inneren Durchmesser von 73,02 mm (2-7/8 - Zoll) aufweist.

5. Hochdruckschlammschaum-Erzeuger nach Anspruch 2,
dadurch gekennzeichnet, daß er zwei Schlammeinläße (68; 70) unter rechten Winkeln zum Gaseinlaßkanal (64) aufweist.

6. Hochdruckschlammschaum-Erzeuger nach Anspruch 2,
dadurch gekennzeichnet, daß er zwei Gaseinlaßkanäle aufweist, wobei jeder eine Buchse (50) aufweist, durch welche das Gas unter rechten Winkeln zu dem Zementeinlaß strömt.

7. Hochdruckschlammschaum-Erzeuger nach Anspruch 3,
dadurch gekennzeichnet, daß die Buchse in eine Ausnehmung (60) des Verbinders (62) paßt und durch ein Paßstück (76), welches betriebsmäßig mit dem Gaseinlaßkanal (64) in Eingriff ist, festgehalten ist.

8. Verfahren zur Herstellung eines aufgeschäumten Schlamms zur Verwendung beim Bearbeiten von Bohrungen, umfassend: Pumpen eines Schlamms, welcher durch einen Schaumerzeuger gemäß einem der Ansprüche 1 bis 7 aufschäumbar ist,
Pumpen eines Gases zu dem Schaumerzeuger,
dadurch gekennzeichnet,
daß das Gas in eine Mehrzahl von Hochgeschwindigkeitsströmen aufgeteilt ist.

Revendications

1. Un générateur de pâte épaisse mousseuse de ciment à haute pression comprenant :
une source de liquide ;
une source de gaz ;
un moyen de combinaison du liquide et du gaz de manière à former de petites bulles de gaz dans le liquide ;
le moyen de combinaison incluant un boîtier (36) et un connecteur (62) à canaux multiples comprenant une zone de mélange (90) reliée à des entrées et à une sortie du boîtier ;
un canal du connecteur étant l'entrée du gaz (64), au moins un canal (68, 70) étant l'entrée de la pâte épaisse, et un canal étant la sortie de la pâte épaisse mousseuse, caractérisé en ce que le canal d'entrée de gaz est pourvu d'une douille (50) comportant une série de canaux (52) de petit diamètre, parallèles à l'axe longitudinal de ladite entrée.

2. Le générateur de pâte épaisse à haute pression selon la revendication 1, caractérisé en ce que la douille comprend un disque d'éclatement (58) qui y est monté et qui provoque un éclatement au cas où les canaux se bouchent et où la pression dépasse une certaine limite, grâce à quoi le mélange de la pâte épaisse et du gaz continue, même si les trous se bouchent.

3. Le générateur de pâte épaisse à haute pression selon la revendication 1 ou 2, caractérisé en ce qu'il existe 16 trous (52) d'un diamètre de 19,05 mm (3/4 pouce) et que le diamètre d'alésage d'entrée est d'environ 63,5 mm (2-1/2 pouce).

4. Le générateur de pâte épaisse à haute pression selon la revendication 1 ou 2, caractérisé en ce qu'il existe 16 trous (52) d'un diamètre de 2,32 mm (3/32 pouce) et que le diamètre d'alésage' d'entrée est d'environ 73,02 mm (2-7/8 pouce).

5. Le générateur de pâte épaisse mousseuse à haute pression selon la revendication 2, caractérisé en ce qu'il comprend deux entrées de pâte épaisse (68, 70) formant des angles droits avec le canal d'entrée (64) de gaz.

6. Le générateur de pâte épaisse mousseuse à haute pression selon la revendication 2, caractérisé en ce qu'il comprend deux canaux d'entrée de gaz pourvus chacun d'une douille (50) que le gaz traverse en formant un angle droit avec l'entrée du ciment.

7. Le générateur de pâte épaisse mousseuse à haute pression selon la revendication 3, caractérisé en ce que la douille s'ajuste dans un évidement (60) du connecteur (62) et est maintenue en position par un adaptateur (76) qui vient en prise en fonctionnement dans le canal d'entrée (64).

8. Le procédé de fabrication d'une pâte épaisse mousseuse à utiliser pour des traitements en puits comprenant les étapes consistant à :

pomper, vers un générateur de mousse selon l'une quelconque des revendications 1 à 7, une pâte épaisse susceptible d'être rendue mousseuse ;

pomper un gaz vers le générateur de mousse ;

caractérisé en ce que ledit gaz est séparé en une série de courants à haute vitesse.

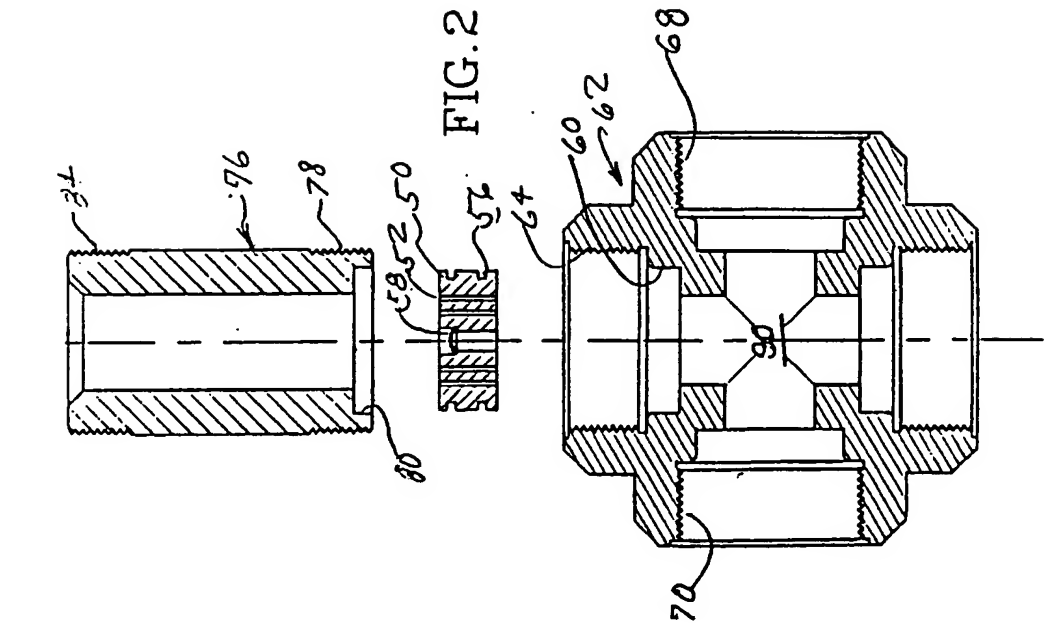
74
76
78
52
50
54
64
60
62
68
80
66
70

FIG.2

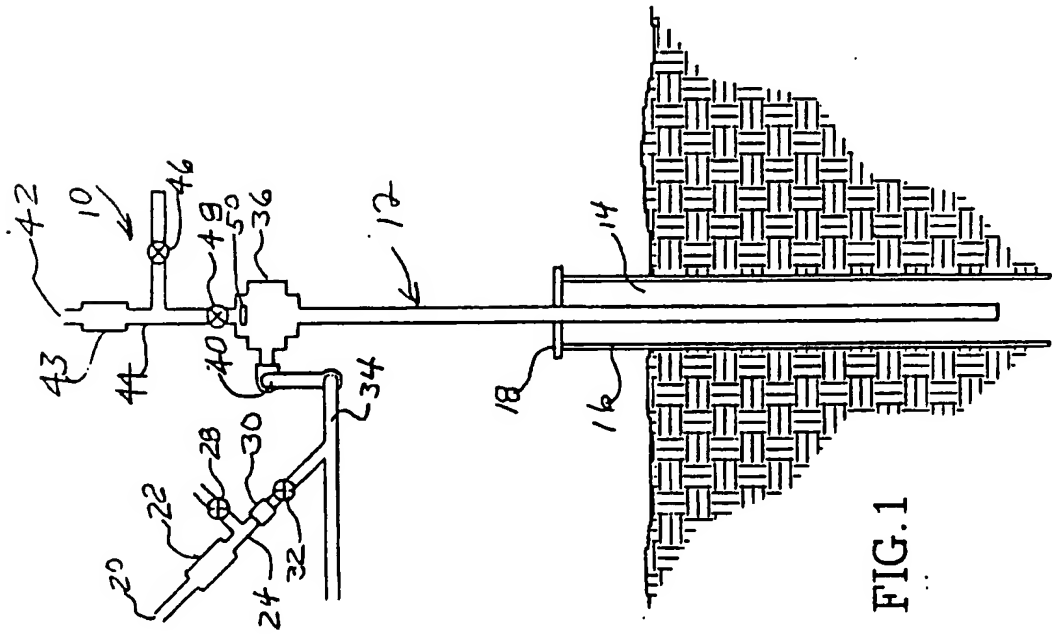
42
10
46
48
50
36
12
14
43
44
40
34
18
16
28
30
22
20
24
32

FIG.1

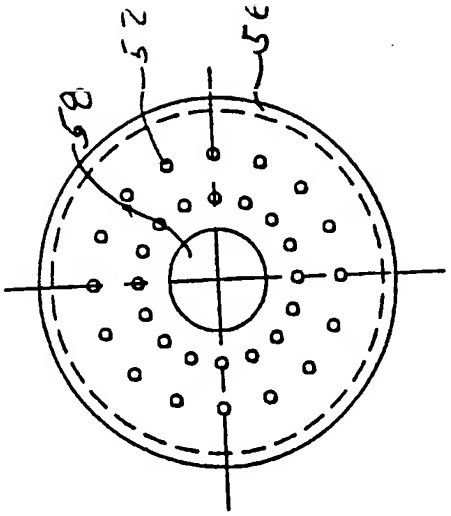

FIG. 4

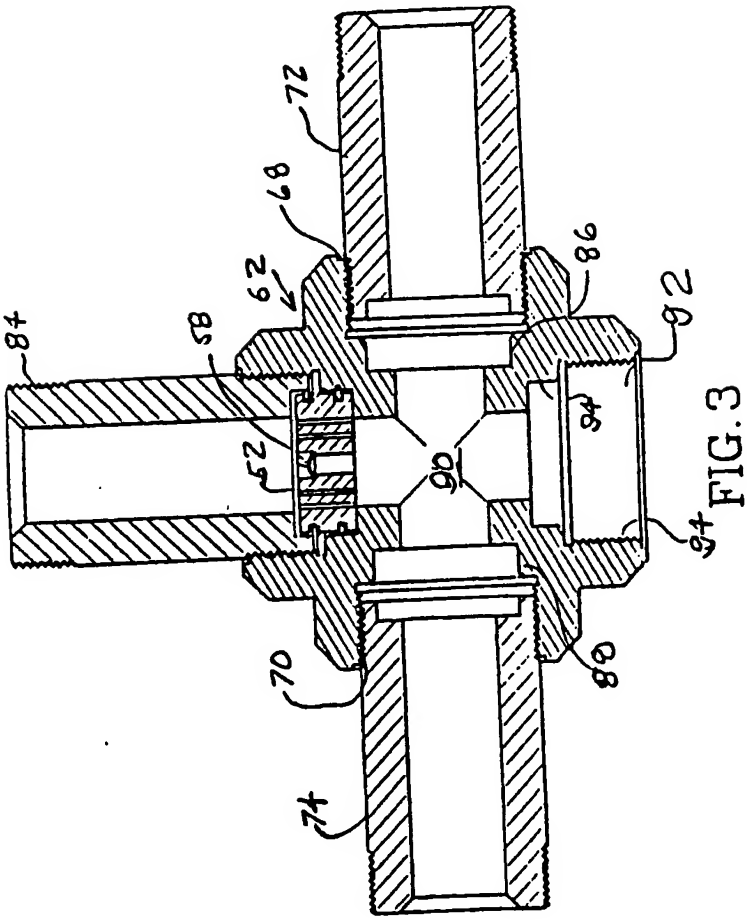

FIG. 3

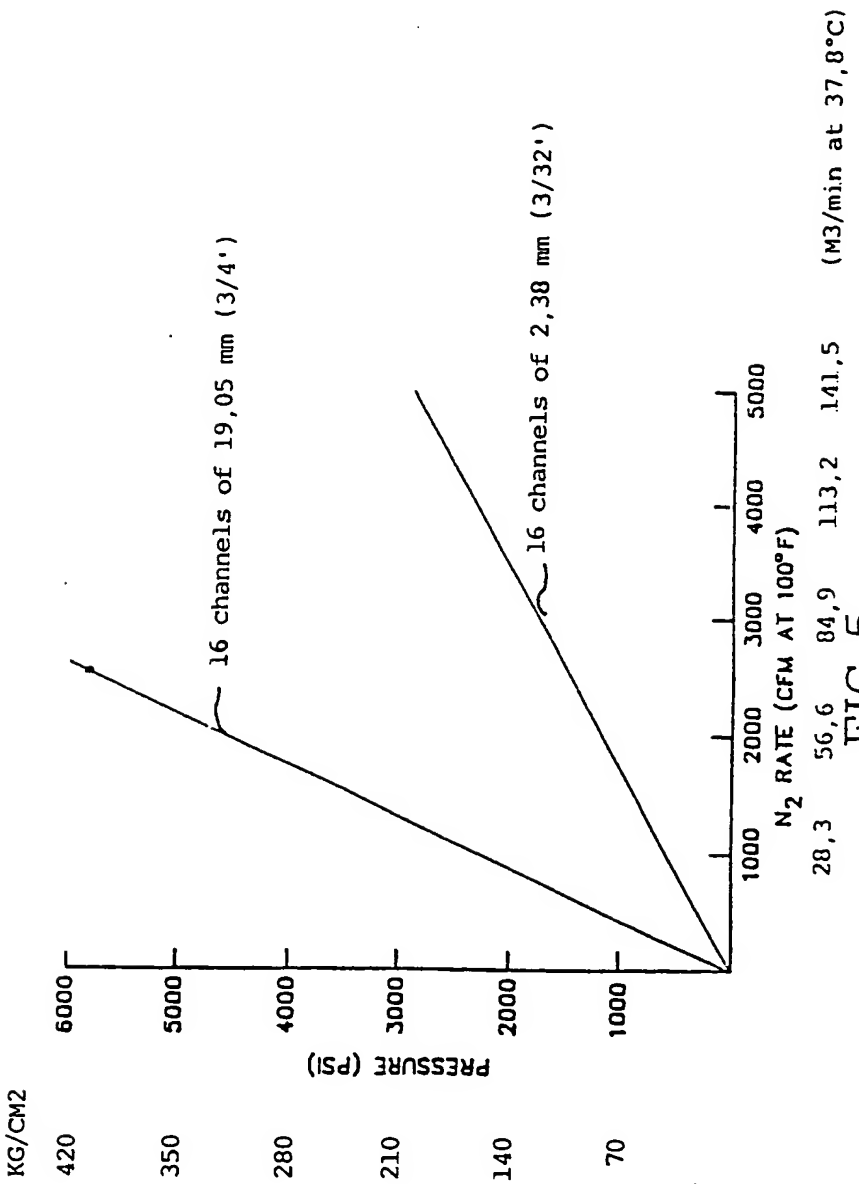
KG/CM2
420
350
280
210
140
70
PRESSURE (PSI)
6000
5000
4000
3000
2000
1000
16 channels of 19,05 mm (3/4')
16 channels of 2,38 mm (3/32')
1000
2000
3000
4000
5000
N2 RATE (CFM AT 100°F)
28,3
56,6
84,9
113,2
141,5
(M3/min at 37,8°C)

FIG. 5